Irrigation of Forage Crops In Eastern United States

Production Research Report No. 59

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
In cooperation with the
Alabama Agricultural Experiment Station

CONTENTS

Washington, D.C. Issued August 1962

Irrigation of Forage Crops in Eastern United States

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It is extremely difficult to evaluate whether or not irrigation of forage pays under humid conditions. Prevailing market prices for livestock, milk, and hay; how the forage is used; cost of producing the forage and establishing and maintaining the irrigation system; availability of water; and management practices must all be considered.

The response of forage crops to irrigation will vary considerably from year to year and between seasons of a given year. Supplemental irrigation may be needed only occasionally during short drought periods or it may be needed almost continuously to produce grazing or forage for silage and hay. Studies show that yields may be reduced by drought periods at many locations almost every year (*43*, *45*, *66*, *67*, *68*, *69*, *72*).[2]

This bulletin reports results from irrigation studies conducted by the author and reviews reports on irrigation studies in relation to forage crops produced in the humid areas. Recommendations are given to those who plan to use an irrigation system.

MOISTURE SUPPLY

Although rainfall is usually high in most of the Eastern States, drought often occurs during critical growth periods and crop yields may be reduced drastically. In those States where the average rainfall exceeds 50 inches per year, drought periods of 2 or more weeks' duration frequently occur (*33*, *43*, *53*, *66*, *67*, *68*, *69*, *72*). Moisture is often provided by summer storms of short duration and high intensity (*64*) that result in large losses of water from runoff, especially on soils of low intake and low storage capacities. Moisture deficiencies for plants are also increased by excessive evaporation from the soil surface, which is caused by high temperatures.

Water is lost from the soil by the combined processes of evaporation from the soil surface and by transpiration from plants, termed "evapotranspiration." When temperatures are high, soil moisture is lost by evapotranspiration at a faster rate than under low temperatures. An application of irrigation water will last much longer under cloudy, cool conditions than an equal amount during clear, hot weather (*28*).

[1] The facilities of the Department of Agronomy and Soil, Auburn University, Auburn, Ala., and the advice and technical assistance of members of the department are gratefully acknowledged.

[2] Italic numbers in parentheses refer to "Literature Cited," p. 22.

The soil may increase or decrease the probability of drought—soil particle size (sand, silt, or clay), depth of soil, and the presence of impermeable layers affect infiltration and water-holding capacity. If compact layers, such as traffic pans, are present in the soil, plant roots may not obtain moisture from the subsoil; also, water intake from rains and irrigation may be restricted.

An adequate and reliable supply of good-quality water (*71*) must be available for an irrigation system. Even though there may be a critical need for irrigation, many farmers will not be able to irrigate. With the increase in use of available water by domestic and industrial consumers, the competition for available water supplies will become more critical in the future (*49*, *57*). Before purchasing an irrigation system farmers must determine if available water sources are sufficient to meet their irrigation requirements at the time water is needed.

IRRIGATION STUDIES

Pasture Irrigation

Information published from Georgia (*16*), Kentucky (*53*, *60*), North Carolina (*42*), and Tennessee (*14*, *59*, *70*) indicates that supplemental irrigation on permanent pastures was profitable. Research data from Tennessee are given in table 1. Studies in Illinois (*30*, *39*) and Michigan (*61*, *62*), however, showed that the increased production from supplemental irrigation was not enough to offset the high cost of

TABLE 1.—*Forage and milk production from irrigated and nonirrigated alfalfa–Ladino whiteclover–orchardgrass pasture at Lewisburg, Tenn., 1951–54* [1]

Year and irrigation schedule	Calculated TDN from pastures [2]	Total milk produced, 4 percent FCM [3]	Milk production attributed to pasture	Gross income per acre [4]	Water applied	Rainfall (April–October)
	Pounds per acre	*Pounds per acre*	*Pounds per acre*		*Inches*	*Inches*
1951:						
Nonirrigated	3, 178	9, 137	6, 012	--------	--------	20. 01
Irrigated	4, 677	13, 975	9, 042	$121	24. 33	20. 01
1952:						
Nonirrigated	2, 243	6, 725	4, 190	--------	--------	21. 16
Irrigated	3, 392	10, 401	6, 504	110	14. 80	21. 16
1953:						
Nonirrigated	3, 025	9, 096	5, 776	--------	--------	19. 77
Irrigated	4, 252	13, 094	8, 027	62	20. 69	19. 77
1954:						
Nonirrigated	1, 784	6, 018	3, 508	--------	--------	20. 54
Irrigated	4, 073	10, 778	7, 253	102	19. 89	20. 54
Average:						
Nonirrigated	2, 557	7, 744	4, 875	--------	--------	20. 37
Irrigated	4, 099	12, 085	7, 706	99	19. 93	20. 37

[1] Adapted from reference (*70*).
[2] TDN=Total digestible nutrients.
[3] FCM=Fat corrected milk.
[4] Increase above cost of feed and irrigation.

irrigation (table 2); management practices in these areas must be improved before irrigation could be justified. In Indiana (*32*) irrigation of pastures more than doubled their livestock-carrying capacity.

Information from the Northeastern States indicates that pasture irrigation may be profitable on some farms (*3*, *18*, *35*, *54*) and unprofitable on others (*1*, *7*, *19*, *24*, *55*, *74*). Costs varied greatly from farm to farm, depending on the initial investment, proximity of water, and the use made of the system. If management problems are solved and if an adequate water supply is available, pasture irrigation in the Northeast may become a more common practice (*58*).

Irrigation of permanent pasture may be profitable when the pasture is grazed by either beef cattle or dairy cattle; however, based on long-term market prices the margin of profit will usually be much higher when the forage in converted into Grade A milk rather than beef or lower grade milk (*14*, *16*, *40*, *53*, *73*, *76*). Since the growing season for most pasture species extends over a long time, large quantities of water are usually needed for pasture irrigation; therefore, irrigation water must be applied as cheaply as possible if a profit is to be realized when soils and topography are suitable. Surface irrigation will usually be cheaper than sprinkler systems for irrigating for pasture.

Several indirect advantages may result from irrigation of pastures. For instance, yields of whiteclover-grass mixtures will often be considerably higher the year following irrigation, mainly because the additional water was responsible for maintaining good stands of clover (*12*, *13*, *17*, *21*, *40*, *44*, *61*). Maintenance of good clover stands through the hot summer months in the Southeast will usually mean earlier fall grazing (*12*).

With irrigation, uniform grazing conditions and high palatability of forage can be maintained throughout the grazing season (*14*, *70*). As a result, the livestock program is not dependent on normal rainfall conditions. A survey in Kentucky (*53*) showed that most farmers

TABLE 2.—*Forage and milk production from irrigated and nonirrigated alfalfa–Ladino whiteclover–bromegrass pastures near Battle Creek, Mich., 1952–54* [1]

Year and irrigation schedule	Forage yield	Milk production, 4 percent FCM [2]	Water applied
	Tons per acre	*Pounds per acre*	*Inches*
1952:			
Nonirrigated	3. 77	3, 280	----------
Irrigated	4. 08	3, 450	1. 5
1953:			
Nonirrigated	3. 50	3, 590	----------
Irrigated	4. 63	4, 810	5. 5
1954:			
Nonirrigated	4. 79	4, 680	----------
Irrigated	5. 37	5, 360	3. 0
Average:			
Nonirrigated	4. 02	3, 850	----------
Irrigated	4. 69	4, 540	----------

[1] Adapted from reference (*62*).
[2] FCM=Fat corrected milk.

estimated they could carry 20 to 50 percent more livestock in a good rainfall year than in an average year. The usual rate of understocking was about 33 percent of an average year's capacity. Fear of drought and of being forced to sell the livestock before they are finished out were the main reasons for understocking.

An irrigation system may often mean the difference between obtaining a good stand and replanting a pasture. Sufficient moisture at this time would result in a savings in seed cost and land preparation. Many forage species are seeded in the fall; in the Southeast, droughts are most frequent at this time and grazing is usually short (fig. 1.).

An irrigation system may enable farmers to harvest one crop and then immediately plant a second crop and obtain good stands. Irrigation for a second crop would often mean better utilization of land, labor and equipment.

Hay Production

Supplemental irrigation may be used to produce high-quality hay; however, as long as hay prices remain relatively cheap, irrigation will not pay unless the cost of applying water is reduced considerably below the present average (1960). Alfalfa and Coastal bermudagrass have produced higher hay yields under irrigation in the Southeast (*15*, *22*, *31*, *73*), especially when the crops were well fertilized (table 3). Alfalfa, a high-quality hay producer, is used in mixtures with grasses and other legumes for grazing, as well as for hay in the Northeast and North Central States (*4*, *36*, *62*). However, only small increases in yields of hay from irrigation have been reported in these areas (tables 4 and 5).

Temporary Grazing

Irrigating adapted, high-producing summer annual forage crops for temporary grazing is more profitable than irrigating permanent pasture (*2*). Yields of annual forage crops increased markedly where irrigation was used (*45*). Irrigation makes it possible to shift

TABLE 3.—*Total hay yields of Coastal bermudagrass at various rates of nitrogen, with and without irrigation, State College, Miss., 1954* [1]

Nitrogen applied (pounds per acre)	Dry matter per acre [2]		
	Irrigated [3]	Nonirrigated	Increase for irrigation
	Pounds	*Pounds*	*Pounds*
0	7, 180	5, 850	1, 330
200	17, 080	14, 520	2, 560
400	19, 860	17, 950	1, 910
600	23, 350	17, 850	5, 500
800	21, 120	19, 610	2, 110

[1] Adapted from reference (*30*).
[2] Rainfall from May 27 to Oct. 13, 10.68 inches.
[3] Total irrigation water applied, 16.60 inches.

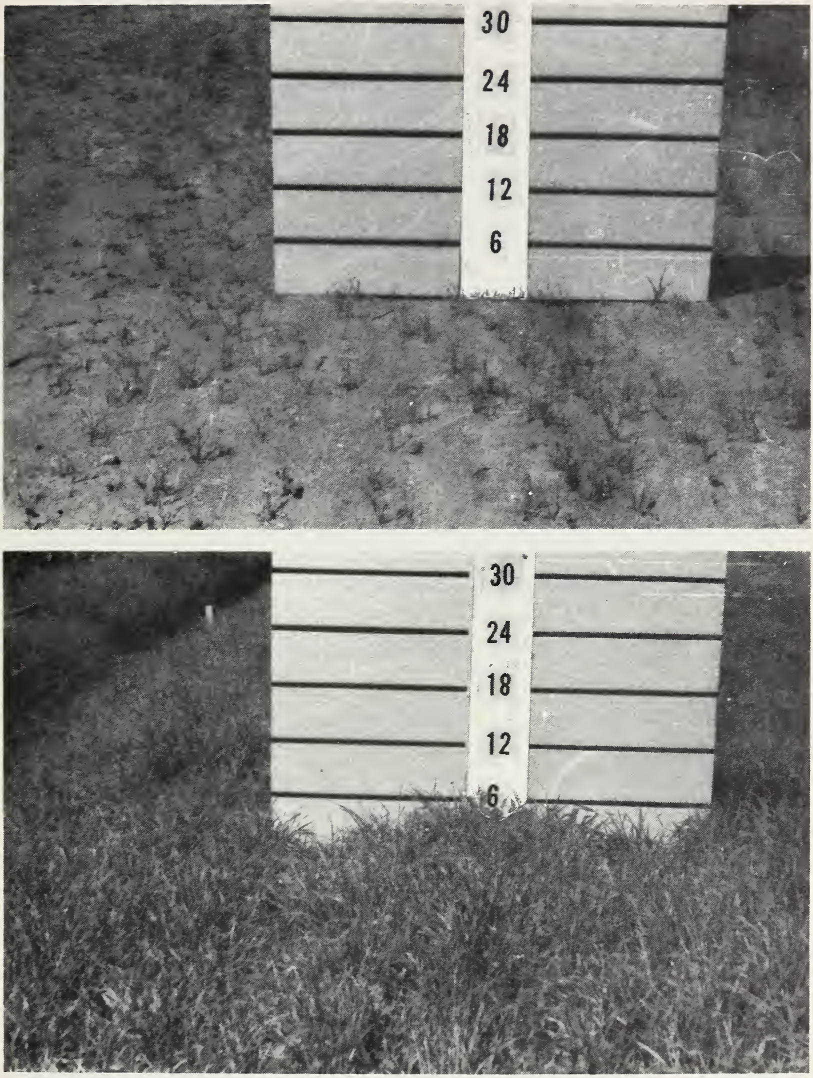

FIGURE 1.—A mixture of rye, ryegrass, and crimson clover planted on August 17, showing stand and amount of growth produced without irrigation (top) and with irrigation (bottom) on September 11. The irrigated mixture had produced approximately 1.63 tons of dry forage per acre by October 15. Thorsby, Ala.

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TABLE 4.—*Hay yields of various plant species and associations, with and without irrigation, at University Park, Pa., 1957–58* [1]

Crops and quantity of irrigation water	Dry matter produced for plots[2]—					
	M_1		M_2		M_3	
	1957	1958	1957	1958	1957	1958
	Tons per acre	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*	*Tons per acre*
Alfalfa	3. 71	3. 79	3. 78	3. 50	3. 95	3. 72
Alfalfa and orchardgrass	4. 18	4. 57	4. 31	4. 72	4. 38	4. 54
Birdsfoot trefoil	3. 07	2. 86	3. 47	2. 19	3. 25	2. 57
Birdsfoot trefoil and orchardgrass	2. 90	3. 88	3. 58	3. 28	3. 51	3. 90
Ladino whiteclover	1. 33	. 41	2. 14	. 32	1. 87	. 45
Ladino whiteclover and orchardgrass	2. 13	2. 01	2. 83	2. 17	2. 68	2. 17
Orchardgrass	2. 17	3. 30	2. 78	3. 45	2. 56	3. 03
	In.	*In.*	*In.*	*In.*	*In.*	*In.*
Irrigation water applied	0	0	9. 16	5. 0	4. 35	1. 0

[1] Adapted from reference (*4*).
[2] M_1=no irrigation; M_2=irrigated to field capacity when 30 percent of the available water was depleted at the 4-inch soil depth; M_3=irrigated to field capacity when 85 percent of the available water was depleted at the 4-inch soil depth.

TABLE 5.—*Dry-matter yields of alfalfa and bromegrass mixture, irrigated at different levels of water, Cornell University, New York, 1953–54* [1]

Irrigation treatment	Yield		Total water received
	1953	1954	
	Lb./acre	*Lb./acre*	*Inches*
No irrigation	1, 790	4, 080	[2] 15. 18
Low irrigation	2, 440	4, 180	19. 91
Medium irrigation	2, 520	4, 270	21. 71
High irrigation	2, 460	4, 300	22. 61

[1] Adapted from reference (*36*).
[2] Rainfall for season.

the growing period of annual forages into the critically dry fall season by growing such crops as millet and sudangrass. With increased moisture and added fertilizers, these crops make rapid growth during a period when grazing is usually short (*21*, *56*) (fig. 2). In a study at Thorsby, Ala., in 1955, Starr millet and alfalfa, drilled in alternate rows late in August and irrigated, produced more than 4 tons of high-quality forage in September and October and the alfalfa was well established for the winter (*45*). Very little growth was made without irrigation (fig. 3).

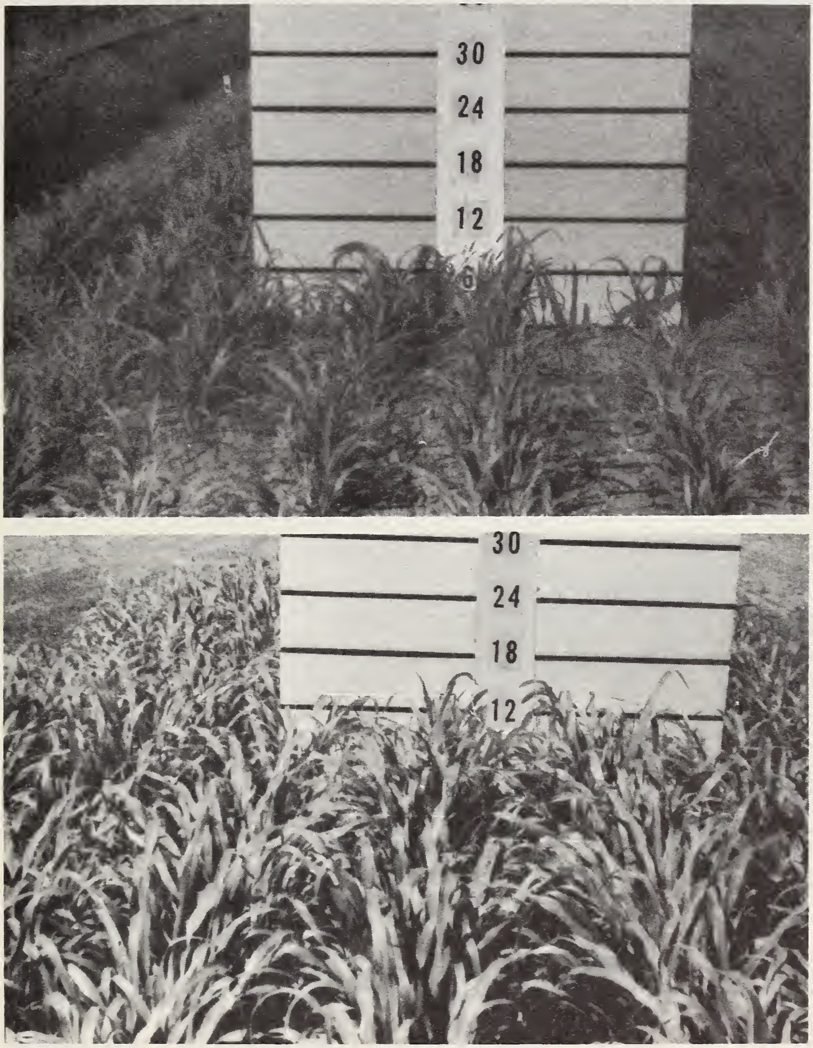

FIGURE 2.—An August 17 planting of Starr millet without irrigation (top) and with irrigation (bottom), showing amount of growth produced by September 11, or 24 days from planting. Thorsby, Ala.

FIGURE 3.—An August 17 planting of Starr millet and alfalfa, interseeded in alternate rows 14 inches apart, without irrigation (top) and with irrigation (bottom), showing amount of growth produced by September 4, or only 17 days. Irrigated area received 1.50 inches of irrigation water during this period. Thorsby, Ala.

Establishment of Stands

Irrigation is valuable in obtaining good stands of fall seedings of small grains, grasses, and legumes. In 1953 in Kentucky, farmers using irrigation were able to obtain excellent stands of fall seedings of small grains and legumes, whereas farmers in the same community who did not irrigate obtained no stands in many cases (*53*).

A delay of a week or more in obtaining a good stand of forage may mean the loss of badly needed grazing or forage. If an irrigation system that is already being used to irrigate high-value cash crops can be diverted temporarily to establish stands of forages, the overall per-acre cost of irrigation is reduced. After a uniform stand has been established, many forage species, especially pasture grasses, are not affected by drought so quickly as they are during the period of establishment.

Silage Production

With irrigation, extremely high yields of silage can be produced by a system of double cropping in areas where the growing season permits (*56*). In a study at Thorsby, Ala., in 1956, 1957, and 1958, two plantings of sudangrass, Starr millet, and Sart sorghum were harvested in each of 3 years for silage (table 6). The first planting was made the last week in April and a second planting was made the first week in August. All species were grown at three soil moisture levels and received a uniform application of 1,000 pounds of 0–10–20 fertilizer and 200 pounds of nitrogen per acre for each planting.

Highest yields for each species were obtained at the highest irrigation level, and yields decreased as the soil moisture level decreased (fig. 4).

Irrigation studies conducted in Arkansas (*5*) show that supplemental irrigation produced yield increases of 300 to 500 percent on

TABLE 6.—*Average 3-year green-weight yields per acre of 2 plantings for each year of sudangrass, Starr millet, and Sart sorghum grown with and without irrigation, Thorsby, Ala., 1956, 1957, 1958*

Crop	Yields with [1]—		
	No irrigation	Medium irrigation	High irrigation
	Pounds	*Pounds*	*Pounds*
Sudangrass	32, 070	45, 691	50, 640
Starr millet	61, 443	83, 389	98, 280
Sart sorghum	62, 355	94, 424	99, 510

[1] Irrigation was applied when 65 and 30 percent of the available soil moisture was used in the surface 24 inches of soil for the medium and high irrigation levels, respectively. The amounts applied were as follows:

Medium irrigation: 1956—12.65 inches; 1957—16.5 inches; 1958—6.38 inches.

High irrigation: 1956—20.70 inches; 1957—13.44 inches; 1958—13.41 inches.

Figure 4.—Sweet sorghum for silage, without irrigation on left and with irrigation on right. Irrigated sorghum reached a height of approximately 14 feet at harvesttime.

TABLE 7.—*Effects of irrigation on green weight forage yields of sweet sorghums and soybeans in Arkansas at the main experiment station in 1956* [1]

Crop and variety	Irrigated [2]	Nonirrigated	Increase
	Tons/acre	*Tons/acre*	*Tons/acre*
Atlas sorghum	21. 27	6. 24	15. 03
Sart sorghum	27. 86	5. 14	22. 72
Tracy sorghum	25. 45	6. 60	18. 84
Ogden soybeans	1. 33	. 42	. 91
Lee soybeans	1. 78	. 52	1. 26

[1] Adapted from reference (*5*); rainfall from Apr. 1 through Aug. 31, 10.86 inches.
[2] Irrigation water applied, 14.0 inches.

Sart, Atlas, and Tracy sweet sorghums (table 7). Sart sorghum, sudangrass, and millet yields were increased 200 to 300 percent by supplemental irrigation in Mississippi (*21*).

MANAGEMENT PRACTICES FOR IRRIGATED FORAGES

Management practices used by farmers with irrigation systems will largely determine whether or not profits will be realized from irrigating forage crops (*34*, *45*, *53*, *63*).

Species

Species and varieties of plants that are adapted to a given area should be used. A variety that is adapted to the sandy soils of the Coastal Plains, such as Coastal bermudagrass, may not be adapted to other areas. A species that will produce well on bottom land may be a poor producer on a sandy hillside. Ordinarily, species that tend to go dormant during the summer months should not be irrigated, in an attempt to force out-of-season production. The root system may be seriously damaged or weed growth increased if a high soil-moisture level is maintained. Fescue, orchardgrass, and Reed canarygrass should not be irrigated during the summer months in the Southeastern States, as very little growth will be obtained (*21*).

Fertilization

The response of crops to irrigation depends not only on the amount of water applied but also upon the level of fertility in the soil (*52*). In 1956, a very dry year, a study conducted at Thorsby, Ala., offered a striking example of the interactions between irrigation and fertilization of bahiagrass (*46*) (table 8). In the same study, yields from Coastal bermudagrass showed a similar trend, but with even higher yields, either with or without irrigation. Similar results were obtained with Coastal bermudagrass in Mississippi (*31*) (table 3) and Texas (*15*). During 1957, when rainfall was uniformly

TABLE 8.—*Interaction of nitrogen and moisture level on yield of bahiagrass at Thorsby, Ala., 1956*

Nitrogen (pounds per acre)	Crop yield	
	Nonirrigated	Irrigated
	Pounds per acre	*Pounds per acre*
0	1, 263	2, 547
75	2, 162	4, 983
150	3, 652	8, 364
300	3, 554	11, 514
600	3, 746	15, 432

distributed at Thorsby, yield increases from irrigation were small and the interactions between fertility and moisture management were lacking.

Soil tests made by State agricultural experiment stations determine the needs of a given crop for phosphate, potassium, and lime. In addition, other fertilizer elements such as boron, zinc, and sulfur may be recommended. Forages need enough lime to maintain a soil pH of 6.0 to 6.5.

To obtain uniform growth of grass species during the growing season, nitrogen should be applied in split applications (*2*). If the grass is cut for hay, 40 to 60 pounds of nitrogen per acre should be applied at the time growth starts and the same amount applied after each cutting. Permanent pastures should receive about the same rate at intervals throughout the growing season and just prior to irrigation. The amount of fertilizer elements that can be profitably added, especially nitrogen, will vary with the prices obtained for hay or as forage (*26*).

Grazing

Usually, grazing should not be allowed during or immediately after irrigation (*6*). Cattle allowed to graze before the ground has become firm, may damage the soil structure and the sod.

A system of rotational grazing should be practiced whenever possible. Rotational grazing allows the plant to reach the proper stage of growth before cattle are permitted to graze. If grazing is not uniform or if weeds are present, the area should be mowed. After cattle are removed, fertilizers are applied and droppings spread. A four-field system of rotational grazing will increase forage yields about 25 percent over a system of continuous grazing (*22*). Overgrazing should be avoided.

Plant Diseases

Plant diseases usually increase with irrigation (*8*, *13*). Disease organisms are spread from plant to plant by the splashing of water from sprinkler irrigation systems. Irrigation may intensify the disease by increasing the humidity around plants, thus creating a more favorable environment for disease development (*38*). Plant pathologist J. D. Manzies, U.S. Bureau of Reclamation, Winchester, Wash., has shown that sprinkler-type irrigation spreads bacterial diseases, whereas furrow irrigation does not.

Studies in Alabama show that the disease severity of forage crops grown under low-level and high-level irrigation was small but consistent (*8*). The most prevalent diseases were rust on orchardgrass, pseudoplea leaf spot on whiteclover, and stemphylium leaf spot on alfalfa. *Helminthosporium* spp. on irrigated sudangrass were also a problem, especially late in the growing season. Powdery mildew on red clover was severe on low-level irrigation areas, but seldom occurred on high-irrigation level areas. Damping-off organisms are usually more prevalent under high-moisture conditions.

The choice of disease-resistant varieties and proper crop management practices are most important.

Insects

Damage from insects to forage species may, or may not, be increased by irrigation. Research data show that while one insect may multiply rapidly under irrigated conditions, other insects may be killed or drastically reduced in numbers (*11*). For instance, red spider mites are usually reduced under sprinkler irrigation, as the drops of water break the webs formed by the mites. Chinch bugs and grasshoppers are usually reduced under irrigation; high temperatures and high humidities encourage the spread of a fungus disease that attacks these insects (*41*). Frequent flood irrigation may control wireworms and white grubs. In South Carolina white grubs were controlled by injecting an insecticide into the irrigation water (*11*).

On the other hand, cutworms, thrips, leafhoppers, and armyworms may thrive under irrigated conditions. Information for the control of specific insects can be obtained through the various State agricultural experiment stations.

WHEN TO IRRIGATE

Available data indicate that most forage species should be irrigated so that a relatively high available soil moisture supply is maintained (*20*, *22*). However, the optimum level of soil moisture will vary somewhat, depending upon the plant species and stage of growth (*23*). When plants are small, or during establishment, water should be applied in small quantities and at more frequent intervals than is necessary for established stands. Sufficient water should be maintained in the root zone of the plants to keep them growing at a fast rate. This means that irrigation usually should be started when approximately 50 percent of the available soil moisture has been removed in the surface foot of soil (*6*, *22*). On well-established stands of deep-rooted crops such as alfalfa, Coastal bermudagrass, and tall fescue, the soil moisture content may be allowed to drop to the 50-percent level in the surface 2 feet without seriously reducing yields.[3] However, under such conditions, soil moisture will reach the critical point in a very short time unless water is applied. Time should be allowed in the irrigation schedule to cover the entire area to be irrigated before soil moisture becomes critical.

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[3] Unpublished data from Alabama.

Sufficient water should be applied at each irrigation to bring the soil moisture level back to field capacity. Field capacity is defined as the amount of moisture that the soil can hold against the pull of gravity. In a soil with normal drainage the moisture content will be at field capacity in about 2 days after it has been thoroughly wetted by rain or irrigation. When plants wilt and do not regain their turgidity overnight, the soil moisture content in the root zone of the plants is at the permanent wilting point. At this time, the moisture remaining in the soil is considered to be unavailable for plant growth and plants will die unless water is added. The amount of moisture between field capacity and the permanent wilting point is considered available soil moisture for plant growth. However, the moisture between these two points is not equally available (*27*). Usually plants will show signs of moisture deficiency long before the permanent wilting point is reached.

Various methods may be used to determine when water should be applied. A farmer may best determine irrigation needs by soil and plant examinations. Most plants undergo changes in appearance before less than 50 percent of the available moisture in the effective root zone is lost from the soil (*22*). Signs of reduction in available soil moisture may be slight wilting, changes in leaf color, and leaf arch. Leaf color will change from a bright green to a dark dull green when moisture is limiting. Various other changes in plants may be noticed after experience is gained in detecting drought signs.

To check soil moisture, a soil sample obtained from a depth of 8 to 10 inches is squeezed in the hand. This method, used by Grissom and coworkers (*22*), is explained in detail in table 9. If an examination of both plants and soil reveals a moisture deficiency, irrigation water should be applied as soon as possible. Any prolonged delay in applying water may seriously reduce yields.

Weather records may be used to calculate time to irrigate a given crop. Time to irrigate a given crop can be calculated by knowing the water requirements and keeping a record of rainfall. This method is based on estimated evapotranspiration losses for different locations as given by Van Bavel (*65*) and shown in table 10. A balance of the estimated available soil moisture is maintained by subtracting the water losses by evapotranspiration and by adding water supplied by rainfall and irrigation (table 11). By this method, the time to irrigate is when 50 percent of the available soil moisture is used. The amount of available soil moisture stored in a given soil is determined principally by the size of the soil particle. For instance, a silt or clay soil will retain a much larger amount of water than a sandy soil (*29*). The approximate amount of available water that can be stored in soil of various textures is given in table 12. These values will be helpful in determining irrigation schedules.

The soil moisture level maintained under irrigation will have a big influence on the rate at which water is lost from the soil. When the soil moisture reservoir is full, or near full, losses by evapotranspiration will usually be much higher than when the soil moisture content is near the permanent wilting point (*22*, *25*). Some crops may use as much as 0.3 of an acre-inch of water per day for short periods of peak growth in hot, dry weather when soil moisture is maintained at a high level.

TABLE 9.—*How to determine soil moisture in soil samples*

Available moisture remaining	Feel or appearance of soils [1]		
	Sandy loam soil	Loam and silt loam	Clay loam and clay
None	Dry, loose, flows through fingers	Powder dry, sometimes slightly crusted, but easily breaks down into powdery condition.	Hard, baked, cracked, sometimes has loose crumbs on surface.
50 percent or less (begin irrigation).	Still appears to be dry, will not form a ball.	Somewhat crumbly, but will hold together under pressure.	Somewhat pliable, will ball under pressure. Cracks appear.
50 percent to 75 percent	Tends to ball under pressure, but seldom will hold together.	Forms a ball somewhat plastic, will sometimes slick with pressure.	Forms a ball, will ribbon out between thumb and forefinger.
75 percent to field capacity	Forms weak ball, breaks easily, will not slick.	Forms a ball and is very pliable, slicks readily if relatively high in clay.	Easily ribbons out between fingers and has a slick feeling.
At field capacity	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Same as sandy loam	Same as sandy loam.
Above field capacity	Free water will be released with kneading.	Can squeeze out free water	Puddles, and free water forms on surface.

[1] A ball is formed by squeezing a handful of soil very firmly with fingers.

Table 10.—*Estimated values of daily evapotranspiration during certain months and for different latitudes under specified weather conditions*

Latitude [1] and month	Daily evapotranspiration during—		
	Dull cloudy weather	Normal weather	Bright, hot weather
Between 48° and 40° N.:	*Inch*	*Inch*	*Inch*
April and September	0. 06	0. 09	0. 13
May and August	. 07	. 12	. 18
June and July	. 12	. 17	. 22
Between 40° and 34° N.:			
April and September	. 08	. 11	. 14
May and August	. 11	. 14	. 19
June and July	. 14	. 17	. 23
Between 34° and 30° N.:			
April and September	. 09	. 13	. 16
May and August	. 13	. 16	. 22
June and July	. 14	. 17	. 23

[1] The values given have been expanded by Van Bavel to include the latitudes shown.

The data in table 13 give average daily water losses for several forage species when soil moisture was allowed to drop to various levels before irrigation water was applied. When the soil reservoir was maintained at a high level, water losses by the process of evapotranspiration were considerably higher than when maintained at a low level for all species. The average daily water requirements for most forage species will be approximately 0.2 acre-inch per day under optimum conditions. However, the actual rate will vary according to stage of growth, species, available soil moisture, and the

Table 11.—*Example showing how to use weather records to estimate time to irrigate forages grown in a loam field located between latitude 34° and 40° N.*

Date	Evapotranspiration	Rainfall	Irrigation [1]	Available water
	Inch	*Inches*	*Inches*	*Inches*
July 5		2. 00		1. 80
6	0. 14			1. 66
7	. 23			1. 43
8	. 17			1. 26
9	. 17			1. 09
10	. 23			. 86
11			1. 25	1. 80
12	. 14			1. 66
13	. 17	. 21		1. 70

[1] Crop to be irrigated when approximately 50 percent of the available water in the surface foot of soil has been used and the irrigation efficiency by sprinkler irrigation is 75 percent.

TABLE 12.—*Ranges of available water-holding capacities for soils of different textures* [1]

Soil texture	Available water
	Acre-inches per foot of soil
Very coarse textures—very coarse sands	0. 40–0. 75
Coarse textures—coarse sands, fine sands, and loamy sands	. 75–1. 00
Moderately coarse textures—sandy loams and fine sandy loams	1. 00–1. 50
Medium textures—very fine sandy loams, loams, and silt loams	1. 50–2. 30
Moderately fine textures—clay loams, silty clay loams, and sandy clay loams	1. 75–2. 50
Fine textures—sandy clays, silty clays, and clays	1. 60–2. 50
Peats and mucks	2. 00–3. 00

[1] Adapted from reference (*50*).

general climatic conditions (*25*, *47*, *65*). A soil with a storage capacity of 2 acre-inches of available water in the root zone of plants will hold enough water to last only 10 days under average summer conditions. But to avoid yield losses, irrigation water should be applied when about 50 percent of the available water has been used.

Various measuring devices may also be used to indicate when to apply irrigation water. Among these are commercially available tensiometers and electrical resistance cells. Types of electrical resistance cells that can be purchased are gypsum, fiberglass, and nylon. Most commerically available devices require careful calibration in the specific soil in which they are to be used.

TABLE 13.—*Average daily evapotranspiration rates of various forage species for three soil-moisture levels at Thorsby, Ala., 1957–58*

Crop	Water used per day at irrigation level [1]—		
	M_1	M_2	M_3
	Acre-inch	*Acre-inch*	*Acre-inch*
Red clover	0. 08	0. 16	0. 19
Ladino whiteclover	. 08	. 17	. 20
Intermediate whiteclover	. 07	. 18	. 19
Atlantic alfalfa	. 08	. 18	. 20
African alfalfa	. 08	. 17	. 22
Orchardgrass	. 07	. 16	. 17
Fescue	. 07	. 16	. 18
Reed canarygrass	. 07	. 16	. 17
Dallisgrass	. 09	. 17	. 19
Lespedeza sericea	. 10	. 17	. 19
Bahiagrass	. 10	. 17	. 18
Coastal bermudagrass	. 10	. 17	. 18
Common bermudagrass	. 09	. 17	. 18

[1] Irrigation water was applied when 80, 65, and 30 percent of the available soil moisture was removed in the root zone of the plants for M_1, M_2, and M_3, respectively.

AMOUNT OF WATER TO APPLY

Usually enough water should be applied to replenish completely the soil reservoir at each irrigation. Less water should be applied per irrigation on a sandy soil than on a clay loam soil for a given root zone. For instance, a clay soil may require as much as 2½ inches to recharge completely the soil reservoir in the root zone of the plants, whereas a sandy soil may only require 1 to 1½ inches. When plants are small, frequent irrigation of less than 1 inch may be required to obtain satisfactory growth. After plants become well established, water can be applied in larger quantities and at less frequent intervals. The amount of water used by plants will usually increase as the season progresses from early spring to late summer (*75*), or until the peak growth period is reached by the plant. The amount of water used early in the season, or when plants are small. may be less than one-third of the amount that will be used during peak growing periods. Evapotranspiration rates vary from an average of less than 0.1 acre-inch per day during early spring to more than 0.3 acre-inch per day during peak growing periods in the Southeast.

When plants are clipped, water requirements are usually reduced drastically. The average daily water requirements for several forage species determined before and after cutting for hay are shown in table 14.

TABLE 14.—*Average daily rates of soil moisture loss after and before clipping for 13 forage species at 2 irrigation levels, Thorsby, Ala., 1956*

Species	Moisture loss for—			
	Medium irrigation [1]		High irrigation [1]	
	After clipping	Before clipping	After clipping	Before clipping
	Inch per day	*Inch per day*	*Inch per day*	*Inch per day*
Red clover	0. 12	0. 25	0. 16	0. 22
Ladino whiteclover	. 14	. 23	. 15	. 25
Intermediate whiteclover	. 13	. 22	. 17	. 24
Atlantic alfalfa	. 13	. 23	. 14	. 25
African alfalfa	. 13	. 25	. 20	. 25
Orchardgrass	. 11	. 23	. 16	. 21
Fescue	. 11	. 26	. 16	. 22
Canarygrass	. 11	. 23	. 13	. 23
Dallisgrass	. 15	. 21	. 17	. 18
Lespedeza sericea	. 15	. 20	. 13	. 21
Bahiagrass	. 16	. 20	. 14	. 19
Coastal bermudagrass	. 14	. 21	. 16	. 19
Common bermudagrass	. 12	. 23	. 15	. 18

[1] Irrigated when 65 and 30 percent of the available soil moisture had been used in the root zone for medium- and high-irrigation levels, respectively.

RATE OF WATER APPLICATION

The rate at which irrigation water can be applied will be governed by the method of irrigation—whether sprinkler or surface—and by the soil characteristics. Water intake rates will be much higher on coarse-textured soils than on fine-textured or clay soils (*48*). In general, the finer the soil particles and the steeper the slope, the slower will be the intake rate. Intake rates may also be reduced by impervious or compact layers of soil.

Regardless of the irrigation method used, water should be applied at the proper rate and in amounts that will permit its complete absorption by the soil (*9*). Otherwise, the soil surface may become puddled, which will reduce the intake rate by sealing the soil surface and will result in poor aeration and increased evaporation. If water is applied too rapidly, a waste of water, plant food, and possibly erosion may occur (*37*). Positive control of application rates and amounts can be obtained with sprinkler systems by using proper size and spacing of sprinklers (*6*). Reliable sources of information should be obtained as to the proper rate and amount of water to be applied to a given soil. The Soil Conservation Service Irrigation Guide for each State or irrigation guides supplied by various State experiment stations are available.

IRRIGATION METHODS

Water can be applied to pastures and forage crops by sprinkler irrigation, surface irrigation, and subirrigation. The method used will depend upon the slope of the land, characteristics of the soil, crop to be irrigated, available water sources, and the cost of setting up and operating the system.

Sprinkler Irrigation

The sprinkler method is generally used on land with steep slopes, soils that are rough or too shallow to be leveled, or on deep sandy soils where intake rates are high and loss of soil moisture by deep drainage would be excessive. At present, the sprinkler method is used more than any other method in the Eastern States (*6*). Some advantages of sprinkler irrigation are: (1) The system is mobile; (2) the amount and rate of application can be controlled accurately by size and spacing of sprinklers; (3) the system can be adapted to any kind of terrain or soil type; and (4) the system has a resale value. Some disadvantages of sprinkler irrigation are: (1) High initial cost; (2) high labor requirements in setting up and moving; (3) operation of system requires high pressures, which needs more power; (4) poor water distribution under windy conditions; and (5) labor problems may be serious, especially if the system is operated at night or for several hours at a time.

Cost of installing a sprinkler system will depend on such factors as power requirements or size of pump, size of pipe, pumping distance, and size of field to be irrigated. To reduce pumping requirements to a minimum, the water supply should be located as near to the field to be irrigated as possible. Obtain the services of an experienced technician to assist in layout and design, or have a responsible firm with a trained irrigation engineer design the system (*10*).

Surface Irrigation

Surface irrigation may be done by graded borders, by contour borders, or by furrows (*50*). Characteristics of the soil and topography of the land will determine the type of surface irrigation to use. For surface irrigation the land must be leveled to a uniform grade to permit even application of water; otherwise, areas of low wet spots and high dry spots will result.

Flooding, using graded or contour border methods, is the most economical for irrigating improved pastures and hay crops. Either method can be used on close-growing crops that are not damaged by temporary flooding.

The contour border method should be used on soils of medium to fine texture that have an available water-holding capacity of not less than 1.5 inches per foot of depth or not less than 3 inches for the root zone of crops (*51*). For best results the intake rate should not exceed 0.5 inch per hour. The topography should be smooth and reasonably uniform with the maximum slope not exceeding 1 foot per 100 feet. Sufficient water must be available to permit flooding of each border strip (the area between the dikes) in a relatively short time. Some advantages of contour border method of flood irrigation are (1) the low labor requirements after system is established, (2) efficient and uniform distribution of irrigation water, (3) simple and easy operation, (4) low initial cost of system, (5) maximum utilization of rainfall, and (6) ease in draining.

The graded border method of flood irrigation offers about the same advantages and disadvantages as the contour border method. Usually the strips are transversely leveled between borders and normally run down the predominant slope. In this system a sheet of water advances down the slope between the ridges or borders, with the desired amount of water being applied to the strip by the time the water reaches the lower end. Water enters the soil as it advances down the slope. Slopes should not exceed 2 feet per 100 feet and should be sufficiently uniform to permit land leveling without moving large amounts of soil.

Furrow irrigation may be used under certain conditions in a forage crop program. Species for silage, such as corn, sweet sorghum, and millet that are planted in rows, can utilize this method. In the furrow method water is run down the furrow between the crop rows. The water enters the soil and spreads into the row as it passes through the furrows. This method is used on land where little grading is needed and on soils of medium to fine texture. Loams and clay loams are best adapted to furrow irrigation, because of their high water-holding capacities and water intake rates that are generally within the range that will permit uniform coverage. Water intake rates should not be less than 0.3 inch per hour or more than 4 inches an hour. Because of high intake rates, very sandy soils are not ordinarily adapted to furrow irrigation.

Extreme care must be used in layout and design of the furrow system if satisfactory results are to be obtained. Some things that should be checked very carefully are: (1) Sufficient water supply to satisfy the requirements of the crop acreage to be irrigated; (2) furrow grades that do not exceed 0.3 foot per 100 feet so as to prevent soil erosion (however, grades up to 0.5 foot per 100 feet may be permitted if the length of rows are reduced to prevent the accumulation of enough water to cause erosion); and (3) cross slope that does not exceed 2 feet per 100 feet; however, the slope will depend to a certain extent upon furrow depth. Most of the advantages and disadvantages applying to graded and contour border irrigation will also apply to the furrow system.

For surface irrigation, a pipeline, either buried or laying on the surface, or a system of ditches is used to transport water from the source to the field. Pipes usually cost more than irrigation ditches. However, pipes have the advantage of being permanent, with practically no maintenance, and afford no loss of water in transportation. In addition, if the pipes are buried they require no extra space as that for ditches. In a ditch system, the field is usually irrigated by siphon tubes from the main or lateral irrigation ditches. These irrigation ditches must be kept open and free from weeds and debris. Unless some kind of material is used to line irrigation ditches, serious water losses through seepage and evaporation may occur. Both the pipeline and irrigation ditch systems may constitute a problem in field management, especially where the systems must be crossed with farm machinery.

Subirrigation

Subirrigation can be used in a few areas where special conditions exist—the Everglades, the Coastal Plain Flatwoods of Florida, and in scattered localities with organic soils in Ohio, Indiana, Michigan, Minnesota, and Wisconsin. Subirrigation actually is a method of controlling the water table and involves maintaining it at some predetermined depth. Moisture is then moved into the root zone of the plants by capillary movement. Water is usually introduced through a system of tiles that often serve a dual capacity—for drainage and for irrigation.

GENERAL RECOMMENDATIONS

Irrigation of forage crops will not assure high returns from your investment. Management practices employed along with the irrigation system will largely determine whether or not a profit is realized. Therefore, do not use irrigation for forage crops unless the best possible management practices are also used.

Grow varieties or species of forages that are well adapted to the general area. Whenever possible, use varieties that are disease resistant. Irrigate species that will produce large amounts of good quality feed.

When establishing species to be irrigated, fertilize with the recommended amounts of nitrogen, phosphorus, potassium, and lime. Obtain information after soil tests have been made by the State agricultural experiment stations. Under most conditions apply higher rates of fertilizers where the crop is irrigated. Apply nitrogen in split applications to grasses.

Irrigation is very beneficial in obtaining uniform stands, but good seedbed preparation is more important. Use small frequent irrigations to establish stand.

Consult a qualified irrigation engineer before buying an irrigation system. Make sure that an adequate supply of water will be available at all times. Apply water as soon as the soil moisture content is reduced approximately 50 percent in the surface foot of soil. Most forage species will use this amount of water in about 12 to 15 days on silt loams and in about 6 to 10 days on coarser textured soils. Extremely sandy soils may require irrigation at 4- to 5-day intervals. Complete irrigation of entire area before plants begin to suffer from lack of moisture. To aid in determining when to irrigate, keep a record of both the amounts and dates of irrigation and rainfall. When irrigation water is applied, add enough water to refill completely the soil reservoir.

Do not put cattle on pasture immediately after it has been irrigated. Use a system of rotational grazing whenever possible.

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U.S. GOVERNMENT PRINTING OFFICE: 1962 O—633358

Growth Through Agricultural Progress